The Walt Disney Company

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

February 3, 1999

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
445 12th Street, SW, Room TWB204
Washington, D.C. 20554

Dear Ms. Salas:

On behalf of The Walt Disney Company and it's wholly-owned subsidiary ABC, Inc., transmitted herewith for filing with the Commission are an original and four copies of its Comments in ET Docket 95-18

If there are any questions in connection with the foregoing, please contact the undersigned.

Very truly yours,

Preston Padden

Preston R. Padden

Enclosures

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Walt Disney Imagineering Research & Development, Inc.

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FEB 3 1999

FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

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Senior Vice President and Chief Scientist
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Eric C Haseltine

1 Introduction

Walt Disney Imagineering Research & Development, Inc., part of the Walt Disney Company (TWDC) has over the past year been working closely with TWDC's ABC division and the Digital Microwave equipment manufacturing industry to investigate and understand the implications of the imminent reduction of the 2 GHz Broadcast Auxiliary Spectrum (BAS). We have done laboratory and field testing on some of the available digital equipment; spoken to numerous experts in this field, as well as studied the record on these proceedings.

We have not yet done any testing of analog equipment modified to operate in the reduced spectrum as well as testing on how both analog systems, as well as digital systems can coexist in the new spectrum. As our work will continue throughout 1999, we will address these questions and plan to report on the outcome at that time

Enclosed are our findings to date:

2 Detailed Analysis

2.1 Standard Definition (SDTV) uses of the BAS Spectrum:

Although the 2 GHz BAS spectrum is predominantly used as a means to establish a temporary link for Electronic News Gathering (ENG) and Electronic Sports Gathering, fixed path Studio to Transmitter Link (STL) and other fixed links are also common in areas where signal crowding has not forced these links to higher frequency spectrum. Also as a result of the propagation characteristics of these lower frequencies, longer distance links can be established without the cost burden of multiple repeat sites.

In each of the different uses of the spectrum, a different quality expectation is built in. This becomes important, as when compressing digital video, a compromise has to be made between picture quality versus latency versus occupied bandwidth. As the content of the picture has the most to do with the ultimate compressibility of that image, a wide range of acceptable compression bit rates have emerged in the industry. Adding to that, the technologies that advance the state of the art in compression continue to improve making it difficult for all in the industry to agree on what the ultimate bit rate for a particular application should be. The ranges that have emerged are from 3.5 Mbps for low motion (Talking heads type), moderate latency limited usage video, to 22 Mbps for the best quality, low latency contribution quality standard definition video.

After the reduction of the BAS Spectrum, the remaining 85 MHz could be divided into the same existing number of seven channels by allocating 12.14 MHz for each channel. Although other channel plans have been proposed, we believe that allocating the maximum bandwidth to the existing number of channels will allow for the best utilization based on the bandwidth requirements of that application. It is also possible to subdivide each channel into a number of sub channels, so that in the event certain applications need less bandwidth, multiple applications can be supported in that channel.

To fit the 3.5-22 Mbps into the 12.14 MHz bandwidth a variety of modulation methods and error correcting codes can be used. The most common modulation system is QPSK and with a minimum forward error correcting code of 7/8[1], 16.3 Mbps[2] can be fitted into that bandwidth. If the error correction is increased to ½ to provide for a more robust signal the data capacity of the channel will need to be reduced to 9.3 Mbps. As many MPEG-2 encoders have the capability to be stacked on the data side, one could also use that 16.3 Mbps to encode three 5.4 Mbps signals.

The relationship of bandwidth to data capacity of the channel for a QPSK modulated signal with a typical Spectral Shape Factor of 0.2 and a typical Reed Solomon error code of 188/204 can be expressed with the following formula:

$$\text{Bandwidth} = 1.2 * \text{Data Rate (Mbps)} / [2(\text{QPSK coding level}) * 188/204 * \text{Viterbi Error Code}]$$

The Viterbi error code in this case relates to the typical error rates quoted as ¾, 7/8 etc. The bit rate in this equation relates to the total MPEG-2 bit rate. For practical purposes we used 1 Mbps for audio, control and MPEG-2 overhead for most tests, fewer overhead bits were used for lower bit rate tests and are pointed out in each case.

To fit more than 16.3 Mbps into a 12.14MHz channel, more complex modulation systems have to be used, such as 8PSK and 16 QAM. But as these modulation systems are more prone to errors, multi carrier modulation schemes such as COFDM could be used to provide added reliability and performance. To calculate the bit rate capacity of the higher order modulation systems one can replace in the above equation the QPSK code rate of 2 with 3 for 8PSK and 4 for 16QAM. So the theoretical bit capacity using these higher modulation methods becomes 24.47 Mbps for 8 PSK and 32.63 Mbps for 16QAM with modest 7/8 error correction. For COFDM we need to take into account the data rate loss due to the guard interval.

Still higher order modulation is possible. For example for fixed data links in the data world, synchronous radios do exist that fit 59 Mbps in a 10 MHz channel. However these radios are very expensive, very large and require engineered paths that will make them impractical and unreliable for the mobile and temporary fixed link applications.

To see how well the above theories apply to real world situations, we have over the last six months tested some of the equipment becoming available for digital ENG applications. Most of our testing used QPSK modulation with bit rates below 15 Mbps. We have also briefly tested a modified COFDM DVB-T system up to 21 Mbps in 7.61 MHz. The testing has been both from fixed locations using an ENG van and from moving platforms by using a helicopter.

Our field testing was designed to complement the previous testing done by both Nucomm Inc.[3] and COMSAT Laboratories[4]. These tests concluded that a digital QPSK modulation based transmission scheme using an MPEG-2 transport stream with a data rate of 9 Mbps with a rate ¾ forward error corrector, or a 10.5 Mbps data rate with a rate 7/8 forward error corrector, would produce a signal that was very robust and could overcome even the most severe multipath likely to be encountered in a dense urban environment.

We agree that for most fixed or temporary fixed links the above observation is correct. We however also tested the case of time variant multipath, which occurs when the transmitter, the receiver or both are in motion. These conditions occur when ENG helicopters, motorcycles, or cars are used to cover news and sports events.

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[1] X/Y coding means X number of data or signal bits for every Y number of transmission bits

[2] Assumes spectral shaping factor of 0.20

[3] Letter from Dr. John B. Payne, President, Nucomm, Inc. to Magalie Roman Salas, Secretary, FCC, ET-Docket No. 95-18 filed February 11th, 1998

[4] COMSAT EXPARTE ET Docket 95-18 Dated March 18th, 1998

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For these conditions our tests showed that a somewhat higher error corrector was needed to give good results. We obtained our best results using a prototype multi-carrier COFDM system that used an error corrector of ½ and a guard interval of 1/8.

2.1.1 Equipment and Settings

2.1.1.1 Platforms

2.1.1.1.1 Stationary Platform

The stationary platform we used was the old ABC Washington News Bureau ENG Van. This Van is a 1984 Ford Econoline Van with a 50 foot collapsible antenna mast.

2.1.1.1.2 Moving Platform

Our moving platform for this test was a Bell Jet Ranger helicopter normally used for ENG operations by WABC-TV. In recent years the helicopter has become a standard tool for ENG in most major markets. With a helicopter it is possible to test impairments to a signal at almost any speed and move from a clear line of site path to a partially or totally obstructed path. Using the physical features of New York City it was possible to generate both short and long delay paths from the man made obstructions such as buildings and bridges, and the natural terrain such as the Palisades cliffs along the Hudson River.

2.1.1.2 Antennas

For the field tests three sets of antennas were used

2.1.1.2.1 Transmit Antennas

To transmit from the van a 2x4 offset parabola, Microwave Radio Corporation "Ellipse 2000", with a gain of 23 dBi was used. An operator who used a controller to orient the antenna in azimuth and elevation directed the Ellipse 2000 Antenna toward the receive site. The Vertical antenna polarization mode was used with this antenna. Other antenna polarization modes were also tried but did not result in a better picture.

To transmit from the helicopter we utilized the 15 dBi directional antenna located in the Troll antenna pod mounted under the aircraft. The antenna was attached to a stabilized platform that was controlled by a GPS system that operated a servo, keeping the antenna pointed at the designated fixed receive site independent of aircraft speed or heading changes. A vertically polarized antenna was used. The aircraft flew at an altitude of 1000 feet ASL and at various velocities between hovering and 70 Knots. Average speed was about 30 Knots.

2.1.1.2.2 Receive Antennas

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The receive location was on the roof of a residential building located at 101W 67^{th} Street in New York City. The roof was 620 feet above ground level and had a clear view to the east and south. There were no microwave transmitters located on the roof of this building. Two different type of receive antennas were used at this site. The first an offset parabola, Microwave Radio Corporation "Micro Scan antenna", with a gain of 20 dBi , the second, a Microwave Radio Corporation Ellipse 2000 2 x 4 offset parabola with a gain of 23 dBi. An operator who used a controller to orient the antenna in azimuth and elevation pointed the antennas toward the transmitter. The Vertical antenna polarization mode was used with this antenna. Other antenna polarization modes were also tried but did not result in a better picture.

2.1.1.3 Digital Coders

Because sampling and coding of analog signals increases the bandwidth required to transmit a digital signal beyond the available bandwidth, compression is needed. The Tiernan TE-30, a high performance MPEG-2 encoder was used. This 4:2:2 encoder first samples the input analog NTSC video and quantifies it over 10 bits, then compresses that video. It can handle bit rates from 0.5 to 15 Mbps. The output to the modulator was a DVB compliant ASI bitstream. The Tiernan TDR-600 was used for decoding and Digital to Analog conversion. The input to the decoder was ASI data from the EF Data Demodulator described below.

2.1.1.4 Modems

For the conventional analog feed a traditional FM modulator was used in the van and helicopter. The modulator is one section of the Microwave Radio Corporation Millennium ENG radio. To allow the testing of different digital modulation schemes, an EF Data SDM-2020 modulator was used:

This modem supports:
1. Modulation schemes: QPSK and 8-PSK.
2. Data rates ranging from 1.5 to 100 Mbps.
3. Different FEC rates for the Inner Convolution Coding including: 1/2, 2/3, 3/4, 5/6 and 7/8.

The ASI input to the modulator was ASI data from the encoder, the output, standard 70 MHz IF. The demodulator was an EF Data SDM-2020 demodulator. It has an Integrated Receiver Decoder (IRD) and is designed for a 950 - 1450 MHz input. The unit is typically connected to the output of a satellite dish's Low Noise Block downconverter (LNB). The 70 MHz IF output of this receiver radio was upconverted to 950 MHz using a TIW Systems Model 6000 L Band transceiver. The upconverted output was then connected to the IRD input of the SDM-2020.

A multi carrier modulation scheme was also tested from a moving platform. This was a prototype 2K COFDM unit from NDS with an attached NDS MPEG-2 encoder. This system occupied an 8 MHz channel

2.1.1.5 Radios

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Two different types of radios were used for the tests:

For the analog signal, an MRC "2T10WB" radio was used.

For the digital signal, an FLH- DAR radio, provided by MRC, was used. This heterodyne digital-analog radio is designed to handle up to 45Mbps of compressed data. It uses a 70 MHz IF interface to connect to the modem. As this radio is used for Studio to Transmitter Links in the existing 17 MHz channels in the 2 GHz band and wider bandwidth channels in the 7 and 13 GHz bands, it used a 30 MHz IF bandpass filter. This should be taken into account when interpreting the test data, as when these radios are utilized in narrower channels, the reduced bandwidth of the IF filter could have an adverse effect compared to the performance obtained using the wider bandwidth filters.

In the van we used a mast mount power amplifier to provide a 12 Watt signal at the input of the antenna for each radio. In the helicopter, as we had to combine both the analog and digital signal for simulcasting on two channels and as the digital radio lacked a high power mode, both radios were run in 2-Watt mode. Further losses in the combiner and cable resulted only in a 5-Watt ERPi. By remaining within the 6 mile distance from the receive site, a fade margin of 19 dB was available.

At the fixed receive site a Millennium Central Receiver (CR), provided by MRC, was used to receive and demodulate the analog signal. This Millennium CR receiver is commonly used by ENG operators. The digital signals were received with a Microwave Radio Corporation FLH-DAR receiver. The output of the antenna was connected to a two port power divider. A port was then connected to each receiver. The receive signal levels were identical for both the analog and the digital receivers

2.1.1.6 Control

A rack mounted Pentium II computer running Microsoft NT 4.0 was used to control the different parameters of both the encoder and Modems. The device parameters were grouped into different tests and the modes were changed using National Instruments *Labview* program. The computer was connected via RS-232 ports to the Modems and encoder. The use of the computer increased the efficiency and accuracy of the tests as different combinations of data rate and error correction were tried. The computer also housed an Avtec Systems Bit Error Rate Tester (BERT) card in one PCI slot. This generator was connected directly to the RS-422 port of the Modem. It can run at rates of up to 15 Mbps.

2.1.1.7 Power

All of the equipment in our test rack used 120 volts AC power. For the van the on board 8.5 KW generator was used to power the equipment. For the helicopter, as the power requirements of the test setup exceeded the available power on the helicopter (15 Amps), a 100 Amp/hour Marine grade Gel Cell battery connected to a Statpower Prowatt 800 modified sine wave inverter was used for power. The current draw of the entire system was 35 Amps.

The transmit system package was mounted in a lightweight shock mounted rack. The entire transmit system weighed 255 pounds.

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2.1.2 Stationary Tests and Results

2.1.2.1 Video test sequence

In this test sequence a Betacam SP tape player was used as the video source. The tape that was played back contained the ABC Lab compression test footage which is a culmination of segments that are typical of ABC's daily programming, such as news, sports and entertainment. Figure 1 shows the video test set-up configuration.

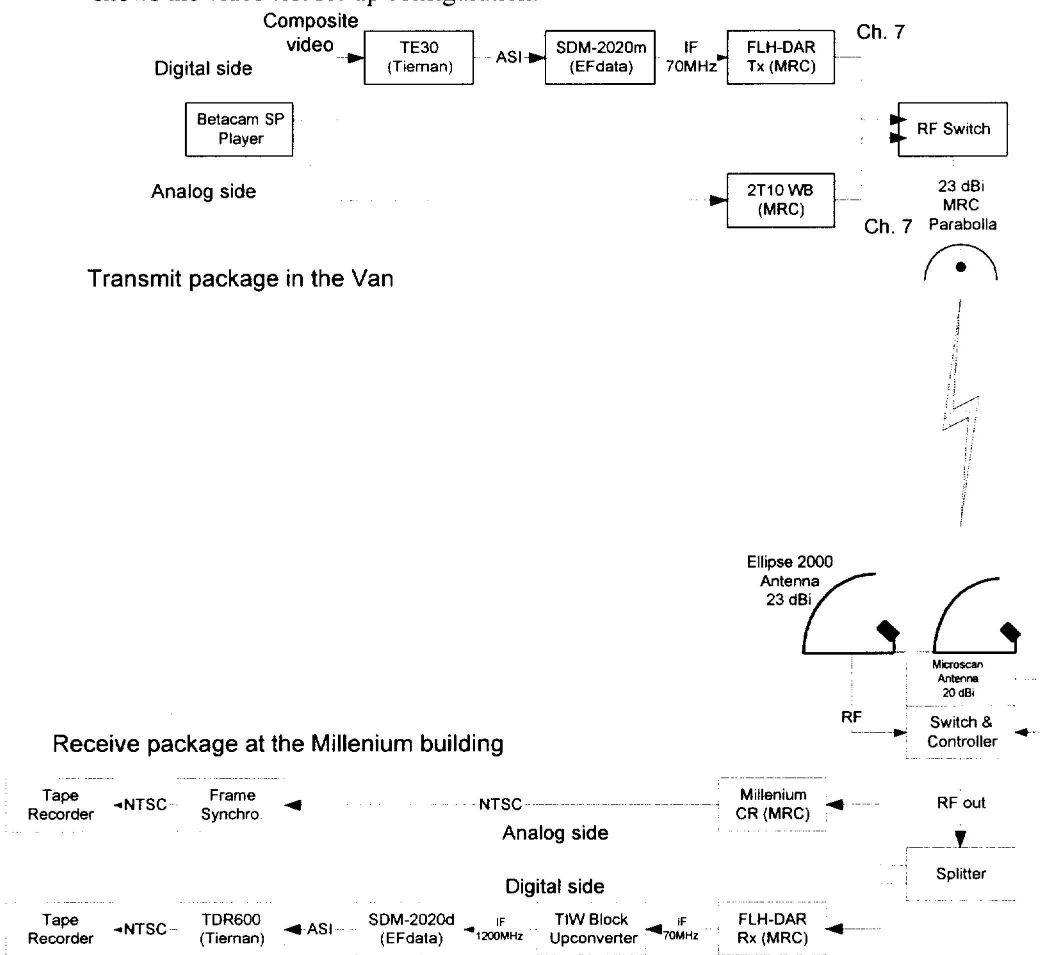

Figure 1 Video test setup

The stationary test was repeated on 4 separate days from various locations and distances to get a good feel of how digital ENG equipment behaves under different circumstances. A typical test sequence would start at 1PM in the afternoon after the local broadcasters had completed their noon news broadcasts and the channels were relatively free from interference. First the test tape would be played through the analog equipment, and after that through the digital system operating at each of the different bit rates and error correction settings without moving the antennas. If time allowed the receive antenna would be moved left and right from the line of sight angle, to see how

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robust the established path was. The signal strength measurements were obtained from the front panel of the FLH-DAR Digital Radio. The performance measurements of the link were obtained from the monitoring utility on the EFData 2020D demodulator. For transmission, both the analog and the digital signal ware transmitted on (2093-2110 MHz.) channel A7. This channel was coordinated with the local user for the duration of the test, although in some of the tests, co-channel interference was observed from an errant source. At the receive site, the demodulated video stream was recorded on a Sony Betacam SP recorder.

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2.1.2.1.1 Stationary Test Results

Day 1:

Date: 12/1/98	XMIT Location: Port Washington Commuter Parking Lot	RCV Location: Millennium Building Roof 101 W 67 Street	Distance: 16 miles	Weather: Partly Cloudy Windy 20-30mph. Visibility clear to horizon
Rcv Antenna: 20dBi Parabola	Noise floor clear channel: -91 dBm	Rcv Ant. Elevation / Azimuth: 6/55 deg magnetic		

Test #	**Settings**	**Channel Bandwidth**	**Rcv signal level**	**Tape segment**	**Raw BER**	**Corr BER**	**Eb/No**	**Comments**
Test-1	Analog	17 MHz	-80dBm	13:39:00-13:42:00				OK picture some noise sparkles on and off
Test-2	Digital 9Mbps ¾	7.81 MHz	-80dBm	13:43:00-13:52:00	1E-4- 8E-5	3E-11	10.5 – 11.3	No errors
Test-3	Digital 10.5Mbps 7/8	7.81 MHz	-80dBm	13:52:00-14:03:00	1E-4- 8E-5	2E-11	8.9 – 10.4	No errors
Test-4	Digital 15Mbps 7/8	11.16MHz	-80dBm	14:04:00-14:11:00	1E-3- 7E-4	2E-11; errors	6 – 8	Data errors when Van is shaking due to strong winds
Test-5	Digital 10.5Mbps 7/8	7.81 MHz	-80dBm	14:12:00-14:20:00	E-4- 9E-5	2E-11	8.6 – 10.4	No errors even though the van is shaking due to strong winds
Test-6	Digital 12.5Mbps ¾	10.85MHz	-80dBm	14:21:00-14:31:00	1E-3- 9E-4	3E-11; errors	7.3 – 8.1	Errors on and off. Co-channel interference started
Test-7	Digital 12.5Mbps ¾	10.85MHz	-76dBm	14:50:00-14:55:00	1E-3- 9E-4	3E-11; errors	7.3 – 8.6	Continues data errors. Co-channel interference

Day 2:

Date: 12/2/98	XMIT Location: Port Washington Commuter Parking Lot	RCV Location: Millennium Building Roof 101 W 67 Street	Distance: 16 miles	Weather: Partly Cloudy Visibility clear to horizon
Rcv Antenna: 23dBi Parabola	Noise floor clear channel: -91 dBm	Rcv Ant. Elevation / Azimuth: 6/56 deg magnetic		

Test #	Settings	Channel Bandwidth	Rcv signal level	Tape segment	Raw BER	Corr BER	Eb/No	Comments
Test-1	Analog	17 MHz	-72dBm	14:45:00- 14:55:00				OK picture some noise sparkles on and off
Test-2	Digital 12.5Mbps ¾	10.85 MHz	-73dBm	15:01:00- 15:10:00	3.1E-4- 6.6E-4	3E-11	8.8-9.2	No errors
Test-3	Digital 15Mbps 7/8	11.16 MHz	-73dBm	15:11:00- 15:19:00	4E-4- 8.5E- 4	2E-11; errors late in the test	7.8 – 8.4	Clear picture. Co-channel interference later in the test as Eb/No drops below 7.1. WABC Northshore towers feed interfering
Test-4	Digital 15Mbps 7/8	11.16MHz	-73dBm	15:24:00- 15:33:00	1E-4- 8E-5	2E-11	9.5 – 12	No errors
Test-5	Digital 6Mbps 7/8	4.46 MHz	-73dBm	15:33:00- 15:59:00	<1E-6	2E-11	13.1 -15.0	No errors. Misaligned antenna by 15 deg. As long as Eb/No is above 6.5 no visible errors

Day 3:

Date: 12/9/98	XMIT Location: Milton Harbor Connecticut	RCV Location: Millennium Building Roof 101 W 67 Street	Distance: 19.5 Miles	Weather: Sunny. Visibility clear to horizon
Rcv Antenna: 23dBi Parabola	Noise floor clear channel: -94 dBm	Rcv Ant. Elevation / Azimuth: 17/20 deg magnetic		

Test #	Settings	Channel Bandwidth	Rcv signal level	Tape segment	Raw BER	Corr BER	Eb/No	Comments
Test-1	Analog	17 MHz	-75.5 dBm	14:20:00-14:29:00				Good signal
Test-2	Digital 12.5Mbps 3/4	10.85 MHz	-76.6 dBm	13:38:00-13:47:00	1E-6	3E-11	13.8-14	No errors
Test-3	Digital 15Mbps 7/8	11.16 MHz	-76dBm	13:56:00-14:04:00	1E-6	2E-11	13.4-13.1	No errors
Test-4	Digital 9Mbps 3/4	7.81MHz	-81dBm	14:17:00-14:26:00	1E-6	2E-11	11.8-12.3	No errors Unexplained drop of level by 5dB during the test
Test-5	Digital 6Mbps 7/8	4.46 MHz	-83dBm	14:48:00-15:00:00	<1E-6	2E-11	10.2	No errors. Unexplained continued drop of level by 2 more dB

Day 4:

Date: 12/11/98	XMIT Location: Milton Harbor Connecticut	RCV Location: Millennium Building Roof 101 W 67 Street	Distance: 19.5 Miles	Weather: Sunny visibility clear to horizon. Windy (25 mph)
Rcv Antenna: 23dBi Parabola	Noise floor clear channel: -96 –97 dBm; -94dBm after 3PM	Rcv Ant. Elevation / Azimuth: 17/20 deg magnetic		

Test #	Settings	Channel Bandwidth	Rcv signal level	Tape segment	Raw BER	Corr BER	Eb/No	Comments
Test-1	Analog	17 MHz	-72 dBm	14:22:00- 14:31:00				Good signal
Test-2	Digital 12.5Mbps 3/4	10.85 MHz	-73 dBm	14:32:00- 14:46:00	1E-6	3E-11	16 dB	No errors
Test-3	Digital 15Mbps 7/8	11.16 MHz	-72 –73 dBm	14:47:00- 14:56:00	1E-6	2E-11	>16 dB	No errors
Test-4	Digital 9Mbps 3/4	7.81MHz	-71dBm	14:57:00- 15:05:00	1E-6	2E-11	>16 dB	No errors. Lost audio during test and had to re-power to get audio back
Retest Test-4	Digital 9Mbps 3/4	7.81 MHz	-74 –75 dBm	15:15:00- 15:24:00	1E-6	2E-11	>16 dB	No errors
Test-5	Digital 6Mbps 3/4	5.21MHz	-73dBm	15:26:00- 15:39:00	<1E-6	2E-11	10.2 dB	No errors 5.5 Mbps Video 256K Audio (2Ch)
Test-6	Digital 5Mbps 7/8	3.72MHz	-75.8 dBm	15:44:00- 15:54:00	<1E-6	2E-11	10.2 dB	No errors 4.5Mbps Video 128K Audio (2Ch)

Day 4 continued:

Azimuth sensitivity tests of 23dBi Receive Antenna

Test #	Settings	Channel Bandwidth	Rcv signal level	Tape segment	Raw BER	Corr BER	Eb/No	Comments
Test-7A	Digital 5Mbps 7/8	3.72MHz	-80dBm		<1E-6	2E-11	10.2 dB	No errors Misaligned rcv. antenna 5 ° cw
Test-7B	Digital 5Mbps 7/8	3.72MHz	-81dBm		<1E-6	2E-11	10.2 dB	No errors Misaligned rcv. antenna 10 ° cw
Test-7C	Digital 5Mbps 7/8	3.72MHz	-87dBm		3.1 – 4.0E-4	2E-11	9.1 dB	No errors Misaligned rcv. antenna 15 ° cw
Test-7D	Digital 5Mbps 7/8	3.72MHz	-89dBm		1.5 – 4.0E-3	2E-11	6.9 – 8.5 dB	No errors Misaligned rcv. antenna 20 ° cw
Test-7E	Digital 5Mbps 7/8	3.72MHz						No Carrier Misaligned rcv. antenna 25 ° cw
Test-7F	Digital 5Mbps 7/8	3.72MHz	-89dBm		4E-2	6E-4	3.7 – 4.2 dB	After antenna was moved 1 ° ccw carrier back. Some errors
Test-7G	Digital 5Mbps 7/8	3.72MHz	-89dBm		1.7E-3	2E-11	6.8 dB	After antenna was moved back to 21 ° cw of strongest signal no more visible errors

Day 4 continued:

Elevation sensitivity tests of 23 dBi Receive Antenna

Test #	Settings	Channel Bandwidth	Rcv signal level	Tape segment	Raw BER	Corr BER	Eb/No	Comments
Test-8A	Digital 5Mbps 7/8	3.72MHz	-72.5 dBm		<1E-6	2E-11	>16dB	No errors Misaligned rcv. antenna 5 ° up in elevation
Test-8B	Digital 5Mbps 7/8	3.72MHz	-68.5 dBm		<1E-6	2E-11	>16dB	No errors Misaligned rcv. antenna 1° down in elevation. Stronger than original signal
Test-8C	Digital 5Mbps 7/8	3.72MHz	-70dBm		<1E-6	2E-11	>16dB	No errors Misaligned rcv. antenna 5° down in elevation. from original signal
Test-8D	Digital 5Mbps 7/8	3.72MHz	-75dBm		<1E-6	2E-11	>16dB	No errors Misaligned rcv. antenna 10° down in elevation. from original signal
Test-8E	Digital 5Mbps 7/8	3.72MHz	-81dBm		<1E-6	2E-11	15.2dB	No errors Misaligned rcv. antenna 15° down in elevation. from original signal
Test-8E	Digital 5Mbps 7/8	3.72MHz	-83dBm		<1E-6	2E-11	13.2dB	No errors Misaligned rcv. antenna 20° down in elevation. from original signal

Day 4 continued:

Azimuth sensitivity tests of 20 dBi Receive Antenna

Test #	Settings	Channel Bandwidth	Rcv signal level	Tape segment	Raw BER	Corr BER	Eb/No	Comments
Test-9	Digital 5Mbps 7/8	3.72MHz	-78dBm		<1E-6	2E-11	>16 dB	No errors Small rcv Antenna in proper alignment
Test-9A	Digital 5Mbps 7/8	3.72MHz	-78dBm		<1E-6	2E-11	>16 dB	No errors Misaligned rcv. antenna 5 ° cw
Test-9B	Digital 5Mbps 7/8	3.72MHz	-81dBm		<1E-6	2E-11	14.3 dB	No errors Misaligned rcv. antenna 10 ° cw
Test-9C	Digital 5Mbps 7/8	3.72MHz	-85dBm		<1E-6	2E-11	11.6 dB	No errors Misaligned rcv. antenna 15 ° cw
Test-9D	Digital 5Mbps 7/8	3.72MHz	-93dBm					No Carrier Misaligned rcv. antenna 20 ° cw
Test-9F	Digital 5Mbps 7/8	3.72MHz	-90.9 dBm		1.3E-2	2E-4	5.6 dB	After antenna was moved 1 ° ccw carrier back. Some errors

Day 4 continued:

Elevation sensitivity tests of 20 dBi Receive Antenna

Test #	Settings	Channel Bandwidth	Rcv signal level	Tape segment	Raw BER	Corr BER	Eb/No	Comments
Test-10A	Digital 5Mbps 7/8	3.72MHz	-79dBm		<1E-6	2E-11	>16dB	No errors Misaligned rcv. antenna 5 ° up in elevation
Test-10B	Digital 5Mbps 7/8	3.72MHz	-84dBm		<1E-6	2E-11	12.8dB	No errors Misaligned rcv. antenna 10° up in elevation.
Test-10C	Digital 5Mbps 7/8	3.72MHz	-88dBm		<1E-6	2E-11	8.8dB	No errors Misaligned rcv. antenna 15° up in elevation. From original signal
Test-10D	Digital 5Mbps 7/8	3.72MHz	-92dBm		2E-2	6E-9	4.8dB	Some errors Misaligned rcv. antenna 20° up in elevation. From original signal

2.1.2.1.2 Conclusion and Notes on Stationary Tests

Based on the data obtained from these tests, we like the versatility and performance of these systems. Although the equipment we used was still immature and will have to evolve for one or two more generations, the promise of clear, noise free video and static free high quality audio is around the corner. We especially like the promise of being able to use multiple video feeds on one channel if the quality and latency requirements are not a prime concern.

The results from day 3 and especially day 4 were very encouraging. As can be seen from the data we were able to receive an impairment free signal with as little as 3 dB C/N.

Day 2 was a windy day where the transmit antenna swayed on and off. The results show this in reduced receive levels.

Another observation was that the swing in the noise floor on different days was rather large. During testing on day 1 and 2 we were intermittently plagued with co-channel interference. This could be attributed to an errant transmit site that was shut down by the end of the second day of testing. Although from this co-channel interference we have some idea of how this affects the desired signal, we still need to do additional testing in the more realistic, adjacent channel, interference to understand how this would affect the signal quality.

As can be seen from the test result, we had a couple of glitches with the equipment. At one point the encoder had to be reset in order to re-acquire the audio signal. At another point we started loosing receive level with no apparent change in atmospheric conditions that would cause that drop. It might have been an overheating power amplifier or other unexplained problem.

We also tried some locations from which it is impossible to receive an analog signal. We were disappointed but not surprised that the QPSK modulated digital signal fared no better and we were not able to receive a digital signal. These locations were the 79 Street boat basin, the south of Staten Island and Bear Mountain. We will retest these areas with the COFDM modems when we get the proper power amplifiers.

The tests were mostly designed to test how the digital system compared to the analog system, and what video at different compression ratios would look like. It is difficult to draw conclusions among different digital systems when the bandwidth of the tested systems varied from test to test. The bandwidth of each system will change the carrier to noise required for error free transmission in that bandwidth as also seen from the Eb/No figures.

2.1.3 Helicopter Tests and Results

2.1.3.1 Video test sequence

In this test sequence the Wescam camera installed beneath the helicopter was used. To have different kind of images, the operator in the helicopter picked different scenes: moving cars on a highway, slow-moving and fast-moving scenes. Figure 1 shows the video test set-up configuration.

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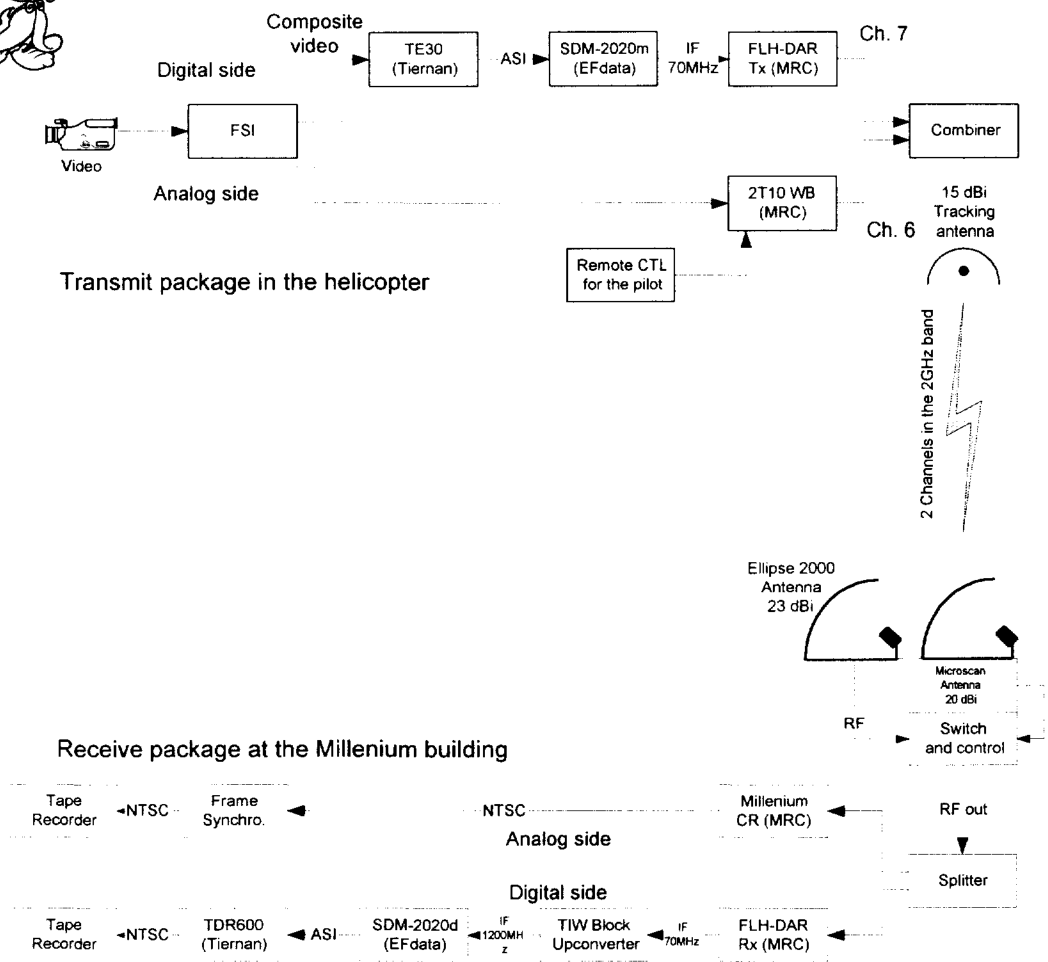

Figure 2 Video test setup for Case 1-3

For transmission, the analog signal was transmitted on channel A6 (2076-2093 MHz.) while the digital signal was transmitted on channel A7 (2093-2110 MHz.). These channels were coordinated with other local users for the duration of the test. During the entire test sequence, a distance of 6 miles or less separated the helicopter from the fixed receive site. At the receive site, the two demodulated video streams were recorded on two Sony Betacam SP recorders. The tapes were later post produced to create a split screen of the analog and digital systems.

The first groups of tests (Case-1, 2,3) were recorded using the EF Data SDM-2020 modem and Tiernan Coders. They were then repeated with the COFDM modulator/encoder combo (Case-4). The remaining equipment for both tests was otherwise identical.

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2.1.3.1.1 System-1 Test Tape

	Mode	Data Bit Rate & FEC	Channel Spacing (20dB Bandwidth
Case-1	Analog FM/ Digital QPSK	- 9 Mbps, 3/4	17 MHz/ 7.38 MHz
Case-2	Analog FM/ Digital QPSK	- 10.5 Mbps, 7/8	17 MHz/ 7.81 MHz
Case-3	Analog FM/ Digital QPSK	- 9.5 Mbps, 2/3	17 MHz/ 9.28 MHz

2.1.3.1.2 System-2 Test Tape

	Mode	Data Bit Rate & FEC	Channel Spacing (20dB Bandwidth
Case-4	Analog FM/ COFDM/QPSK	- 5.53 Mbps, ½, 1/8 Guard band	17 MHz/ 8 MHz

2.1.3.1.3 Conclusion and Notes on Moving Platform Tests

Case-1 and Case-2 both displayed very good pictures while there was line of sight in stationary as well as moving conditions. In multipath conditions picture quality depended on the severity of the multipath and signal strength. If the analog signal was good enough to use for broadcasting a perfect digital signal appeared a second later (Both Re-sync timing as well as coding latency). In time variant multipath the extra error correction in Case-3 allowed for a longer gap of impaired signal before the video image went to black or showed data impairments. As in moving conditions around tall buildings these gaps are frequent, this extra error correction will be necessary. In all above three cases the only time the digital systems did not produce a signal was when the signal would fade from bad to OK but not stay OK for at least a second.

In our testing of Case-4 the system was hampered by the lack of signal strength as COFDM required operating the transmit power amplifier in its linear region and our receive signal level was 5 dB lower than for all previous tests. Even though, the system showed better results than the other systems. In one severe multipath segment it produced perfect images out of a signal that was completely unintelligible on the analog system and had not produced an image for the other digital cases, albeit at reduced error correction rates. We will retest Case-4 again when the manufacturer supplies the unit with a higher power output power amplifier.

2.1.3.2 BER test sequence

While the video test sequence was going on for Case-1 and Case-2 the EF Data Demodulator was polled in one second intervals through the instrumentation computer running the Labview program for its corrected Bit Error Rate count. This data was recorded to a file and tabulated later in Excel. The time variant BERT count for Case-1 and Case-2 is as follows:

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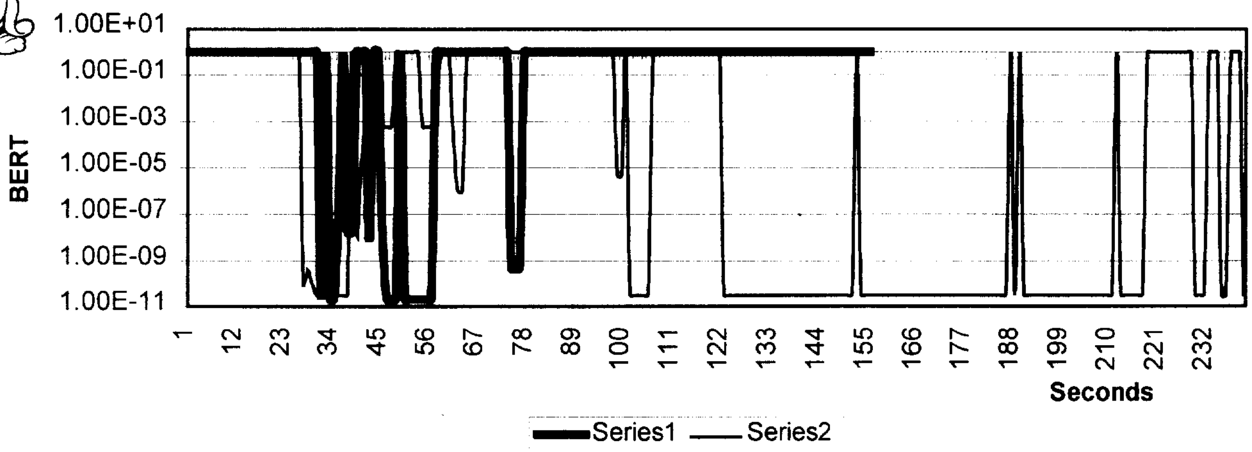

As can be seen from the graphs Series-2 (Case-2 ¾ FEC) is more robust with fewer drop outs than Series-1 (7/8 FEC) as more error correction was applied

2.1.3.3 Re sync times

By examining the recorded video and the BER test, re-sync times for the demodulator (SDM-2020d) and for the decoder (TDR7/G) were approximated. It appeared it was in the order of about one second once the signal strength provided a useable analog picture. This delay has three components, the carrier detect phase, the re-sync of the decoders and the encoder/decoder latency. Encoder/decoder latency was observed at about 250 ms.

2.2 HDTV field production requirements:

As the broadcast industry makes the transition from NTSC to digital broadcasting and HDTV, the issue of the use of BAS Spectrum for HDTV transmission needs to be addressed. Considering that an HDTV signal carries 5 times the bit rate of a 601 Component Digital signal, a bit rate well in excess of 45 Mbps will be required for HDTV contribution quality transmissions. Even with higher order modulation methods, squeezing that many bits into a reliable microwave link at 12.14 MHz per channel will present great difficulties. It is likely that other spectrum will be needed.

We have not yet tested how well these higher bit rates fare in this spectrum. We hope to issue updates as these tests are conducted.

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2.3 The status of available Digital ENG equipment

Most of the equipment used in our testing of Digital ENG systems was designed for the Digital Satellite industry. As such they need to go through one or two more iterations of refinement before they approach the simple elegance that the existing analog systems have, and that is needed in the field for error and hassle free use.

As an example the analog helicopter transmit package was the size of a large car radio weighing about 13lbs and occupying 0.2 cubic feet of space. It had a connection for audio, video and the antenna. It drew about 60 Watts. The front panel had a Power on-off switch and a selector switch for the desired channel.

In comparison our digital ENG testing system consisted of a 255-lbs. lightweight (40lbs.) transportable rack on casters, made out of aluminum and occupying 12 cubic feet of space. It was the size of an airline beverage cart and filled with 13 rack units of equipment. As the power consumption of our package was close to 400 Watts and the power system on the helicopter was only able to provide up to 5A at 24 Volts, an external battery-inverter system was necessary. This system weighed 70 lbs. (included in the 255 lbs.). We should also note that as most of the equipment tested was designed for satellite industry it lacked the 12/24 Volt DC power option that is common in ENG equipment, hence necessitating the inverter. It is possible to derive 400 Watts of power from the helicopter engine, however this would require the redesign of the ships electrical system that could take over a year for approvals from the FAA. As the digital system was not FAA certified it had to be self contained and brought into the cockpit as baggage each day of the test, necessitating the removal of one of the passenger seats to fit in. Even though our test engineer weighed in at only 140 lbs. we were limited to an hour and ten minutes of flight time fuel as a result of all this weight. It is true that the control computer added some weight (35 lbs.) and bulk, but without it, navigating the two different control panels of the encoder and modulator and changing five to seven parameters in each device every time we tested a different mode would have caused errors and burned precious fuel in the air. The myriad of options on the systems caused confusions to us even though all of us were electrical engineers with background and understanding of the subject. The systems have to become more integrated and easier to use before wide deployment is possible.

The final installation of this digital equipment in helicopters will also require EMI testing by the FAA as the newer fly by wire helicopters are susceptible to interference. FAA approvals take a long time.

The receive package faired no better. It was comparable in size and weight and had an additional fourth component, as a block converter was needed to interface a device designed for the satellite industry to a terrestrial microwave device.

All these separate components from different manufacturers also add to the cost of the system as each product has its own casing, power supply, control system and display as well as profit margins.

Some of the tested devices were still in a development stage, missing important options such as frequency agility and sufficient gain to handle long paths. This is understandable since most manufacturers do not want to build products that will become obsolete since the requirements of DENG are still in flux.

Manufacturers also need to incorporate additional features in their products that are necessitated by the delayed and binary nature of digital signals appearing when one tries to establish a link. We often found ourselves using the analog FM signal as our signal strength gauge for the digital system since one easily comprehends the gradual fading in and out qualities of the analog systems, compared to the one second delayed black (no picture) or great picture modes of the digital systems,

We will continue evaluating other available DENG systems since our assessment of the above conditions maybe related to some of the products available but not all.

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2.4 *The status of Digital POV systems*

Point of View (POV) cameras and associated wireless video transmission systems are used frequently in high profile sports events such as the Indy racecar cameras, cameras strapped to downhill skiers, helmets of football players, golf players, sailboats, horses and bobsleds, to create more engaging programming. They are by their nature ultra compact, lightweight and power efficient. Current analog systems are the size of a pack of cigarettes. It is the opinion of the manufacturers of these systems, that it will take about five years to be able to miniaturize cost effectively systems that match their analog counterparts in size, power consumption and capabilities. It is therefore recommended that these systems remain analog FM until that time. It is the opinion of the manufacturers of these systems, that 12 MHz is about the minimum that frequency coordinated professional systems can operate in without significant interference from others

2.5 *The usage of existing analog equipment in narrower bandwidth*

Most of the assumptions that analog FM equipment can be modified to work in 12 MHz channels stem from the current usage of 17 MHz split channels in Los Angeles. By using multiple receive sites, using cross polarized adjacent channels, using only one audio channel, reducing the video deviation and using sharp filters, broadcasters in this area have made the tradeoff between quality and the number of channels available as they needed more than the 7 channels available. While users in Los Angeles have made this work this is not an ideal situation; it may not work or work well in other areas around the country because of the lack of available multiple receive sites and because the "split" channels actually overlap somewhat.

One requirement that has been stressed by many users of ENG systems is that one channel of audio will not be enough for typical production requirements. We will be working with one of the microwave equipment manufacturers to test a 2 audio channel system in 12.14 MHz. We plan to report on these tests as soon as they are concluded.

To properly test adjacent channel performance among various analog and digital modulation schemes in a new band plan requires many pieces of microwave ENG equipment that are specifically tuned and modified to work in the new band plan. As this exceeds our capabilities, we are waiting to start working with one of the microwave equipment manufacturers to conduct these tests. We plan to publish the results of these tests as soon as we have obtained them.

2.6 *Operational Issues*

As we start using digital BAS equipment we will discover that certain operational issues are bound to come up. Some of these will be a mere inconvenience and some a show stopper. The ones that we have come up with during our testing are as follows:

In the analog ENG world it is rather easy to identify an interfering signal. All receive radios are able to demodulate and display the video signal and usually at the beginning or end of the transmission, some form of ID will be displayed identifying the source of the signal.

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In the digital world not only does one have to know the modulation type but various parameters such as error correction specifics and encoding specifics. Equipment manufacturers have to take this into account as they design their next generation systems as some sort of ID will be required to preserve this useful feature.

During our testing we missed the built in signal strength indicators part of the analog systems. Typically in analog systems noise in the audio is the first indication that we have to move the antenna faster to track the transmitter. Then we start seeing the picture becoming noisy. In the digital systems, if we tracked the transmitting antenna too slowly our only indication was after the fact, after we had completely lost both audio and video and had to point blindly for a short while until the signal strength was sufficient to pull in a perfect picture. After we brought out the constellation of the digital modulator that was available on a connector to a scope, we regained our confidence where the degradation of the signal was immediately apparent. Such indication should be incorporated in some form on the control panels of future equipment.

If analog and digital systems will be used at the same time it is important to note that to an analog receiver the digital signal looks like pure noise. So the typical Standard Operating Procedure of "Before you turn your transmitter on look and see if there is another transmitter operating on your channel" is no longer valid. Although the interference of an digital signal into an analog signal looks like a noisy signal, the opposite is not true, as data errors will start causing significant picture ailments.

The operational impact of using compressed wireless cameras in complex productions such as Electronic Sports Gathering (ESG) that also would use uncompressed wired cameras, has to be considered. The increased delay in the compressed wireless camera may have to be added to all the uncompressed wired cameras if inter-cutting between these cameras is a show requirement, depending on the purposes for which the wireless camera is used and the actual amount of latency in the encoder/decoder. This is very costly and impractical, requiring production personnel to adapt to different production techniques where they would not intercut between these cameras. Added delay in the cameras also introduces undesirable production issues such as audio delay, IFB (Interruptible foldback) delays and return video delays.